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Die Infektion beim Brandverletzten

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Cause of mortality in thermally injured patients

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Concomitant with a decreasing mortality rate, a marked change in the cause of death has occurred in thermally injured patients over the last decade. In 1979, a mortality rate of 27.1 % was observed in 273 patients admitted to this Institute. Between the years of 1987 und 1991, an overall mortality rate of 8.5% was observed in 1094 patients with a generally comparable age and burn size distribution compared to the 1979 cohort (Table 1). In 1979, infection was identified as the primary cause of death in 64% of patients, a figure which has declined to 42 % over the past 5 years. In 1979, the mean postburn day of death was postburn day 24, but it has recently increased to postburn day 32.

Of the 1094 patients admitted to this Institute between January 1987 and December 1991, 93 patients died. The mean age of the nonsurvivors was 49 ± 2.6 years with a mean total burn size of $56.7 \% \pm 2.5 \%$. Inhalation injury diagnosed by either bronchoscopy or Xenon scintigraphy was present in 60 of 93 nonsurvivors. Pneumonia occurred in 60 % of the patients and was most commonly diagnosed in nonsurviving patients with inhalation injury. Pneumonia was diagnosed only when the following criteria were met: presence of fever, new infiltrate on chest roentgenogram, predominant organism in sputum culture and sputum leukocytosis (> 25 WBC/hpf). An autopsy was obtained in 52 of the 93 patients (55.9%) (Table 2). The postburn

Table 1. Age and burn size distribution comparing 1979 and 1987-1991

TBSA	Age			
	< 20	21-40	41-60	> 60
< 20	13.9/21.6 *	13.2/26.0	8.0/7.3	1.8/4.7
21-40	5.5/5.7	10.6/9.7	4.0/3.6	1.8/2.4
41-60	5.1/2.6	11.7/6.0	2.2/1.6	3.3/1.3
61-80	1.4/0.5	4.7/2.2	2.5/1.0	0.7/0.36
> 80	1.4/0.3	4.7/1.6	1.8/0.8	0.35/0.4

* = Percent of total admissions 1979/1987-1991

Table 2. Demographics of nonsurvivors (1987-1991) N=93

Age	49.6 ± 2.6 years	(1-92 years)
TBSA	$56.7 \pm 2.5\%$	(0-99%)
Inhalation injury	64.5%	
Pneumonia	60%	
PBD Death	31.6 ± 4.4 days	(0-270 days)
Autopsy	55.9%	

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Table 3. Mortality predictor

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- $A = 6.026$
 - $B = 0.1311 \cdot \text{TBSA}$
 - $C = 0.2525 \cdot \text{Age}$
 - $D = 0.7422 \cdot \text{Age}^2$
 - $E = 0.4203 \cdot \text{Age}^3 / 10\,000$
 - $F = A + B - C + D - E$
 - $\text{MORT} = \text{EXP}(F) / 1 + \text{EXP}(F)$
 - Based upon all patients 1984–1988
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day of death ranged from 0 to 270, with a mean of 31.6 ± 4.4 days. Estimated mortality of the 93 nonsurvivors, using a predictor based upon age and burn size and developed using patient data between the years 1984 to 1988 was $62 \pm 3.6\%$ (Table 3). Analysis of the cause of death in these 93 patients reveals deficiencies associated with burn-related mortality predictors based upon only age and burn size. Such predictors fail to account for the impact of pre-existing disease and other morbidity-related factors not directly related to the burn. When a predictor which accounts for the co-morbid effect of inhalation injury and pneumonia on outcome was used, estimated mortality for this cohort of patients was 76%. The median estimated mortality per patient was 0.897, indicating that the majority of patients had a very high likelihood of dying. Still, the co-morbid effects of pre-existing disease are not accounted for, and some patients with severe pre-existing cardiac or hepatic disease will be projected to have a low likelihood of not surviving.

Twelve of the 93 nonsurviving patients were resuscitation failures. Hemodynamic and pulmonary stability could not be achieved in these patients. Their ages ranged from 2 to 77 years, with a mean age of 35.4 years. Not surprisingly, they had a large mean burn size ($82.7 \pm 4.2\%$). Ten of the 12 patients had a burn size in excess of 80%. The two patients with a burn size less than 80% TBSA both had severe inhalation injury, which added significantly to the difficulty in resuscitating these patients. The predicted mortality of these 12 patients was 93% with a range from 80 to 98%. These patients died, on average, on postburn day 2, with a range of 0 to 5 days.

Ten patients died from cardiac disease. Their average age was 60.4 years with a range of 1 to 91 years. The average burn size was 46.8%, with five of the 10 patients having inhalation injury. Pneumonia occurred in four of the 10 patients. Seven of the patients had a acute myocardial infarction, two had autopsy-documented severe cardiomyopathy, and one 3-month-old child sustained a cardiopulmonary arrest without apparent cause. The predicted mortality in this group of patients was 75%. The mean postburn day of death was 16.5 days and ranged from one to 70 days.

Pulmonary failure was the primary cause of death in 22 of the 93 nonsurvivors. Their mean age was 32.8 ± 4.8 years, with a range of 1 to 69 years. Mean burn size was 62.6% (range 40–86% TBSA). Eighteen of the 22 patients had inhalation injury, and all 18 of these patients developed pneumonia. Of the four remaining patients, three had severe inhalation injury and died early in their postburn course prior to the development of pneumonia, and one patient died from a cardiopulmonary arrest secondary to an accidental extubation. The mean postburn time of death was 26.3 days and ranged from 0 to 120 days. The predicted mortality in this group of patients was 58%. This low predicted mortality indicates the failure of

predictors based only on age and burn size to take into consideration the co-morbid effect of inhalation injury and pneumonia on outcome. When a predictor based upon age, burn size, and the presence of inhalation injury and pneumonia was used, the predicted mortality was 83 %.

Ten patients died from multiple organ failure (MOF) without an identifiable septic focus. Multiple organ failure were defined according to strict clinical criteria and a minimum of three failed systems was required to assign this as the cause of death.

- 1) Respiratory failure as defined by Fulton and Jones which, in general, requires at least 120 h of mechanical respiratory support.
- 2) Cardiac failure based on the criteria of Tilney, which included a cardiac index (CI) of ≤ 2.2 , cardiogenic shock requiring pressor support in combination with elevated pulmonary artery wedge pressures, arrhythmias not metabolic in origin that compromise cardiac output, or electrocardiogram (ECG) and enzyme evidence of perioperative myocardial infarction.
- 3) Hepatic failure defined as a bilirubin greater than 2 mg/dl with elevation of liver enzymes to levels twice normal.
- 4) Gastrointestinal failure defined as bleeding stress ulcers requiring at least two units of blood in 24 h.
- 5) Neurological failure defined as failure to respond to other than painful stimuli, or all grades of coma.
- 6) Renal failure defined as elevation of BUN and creatinine values of twice baseline levels.

The mean age of the MOF patients was 69.7 years (range 35–92 years). The mean burn size of this group was 45 % (0–90 % TBSA). The patient without thermal injury who died of multiple organ failure was a 75-year-old female with severe inhalation injury. Six of these 10 patients had inhalation injury and nine of the 10 developed pneumonia which was treated during their postburn course. The mean postburn day of death was 52.7 days and ranged from 9 to 166 days. The predicted mortality in this group of patients was 61 % using the first predictor and 87 % with the second.

Sepsis accounted for 21 of the 93 deaths. Sepsis was defined as the presence of positive blood cultures in the clinical setting of hypotension, decreased systemic vascular resistance, and increased cardiac index. The mean age of this group of patients was 59.1 ± 4.1 years and ranged from 28 to 88 years. The mean burn size was $62.4 \pm 5\%$. Thirteen of the 21 patients sustained inhalation injury, and pneumonia was present in 17 of the 21 patients. The predicted mortality for this group was 85% using the second predictor. In 13 of the 21 patients the origin of sepsis was clearly pulmonary, with 12 bacterial and one candidal pneumonia diagnosed. One patient with bacterial pneumonia also had bilateral adrenal infarction found at autopsy. Of the remaining eight patients, six had an identifiable source of sepsis: two patients with necrotizing enterocolitis, one patient with klebsiella wound infection and bilateral adrenal infarction, one patient with a gram-negative subacute bacterial endocarditis, one patient with subacute staphylococcal endocarditis, and one patient with fungemia secondary to fungal burn wound invasion. Two patients had gram-negative sepsis without an identifiable primary source at autopsy.

Neurologic complications accounted for seven of the 93 deaths. The mean age of this group was 42.7 ± 12.1 years, and the mean burn size $36 \pm 7.5\%$. Four elderly

patients sustained a CVA at or shortly after the time of their injury and eventually succumbed from their cerebrovascular accident. One patient with significant head trauma and relatively minor burns died from his head injury. One patient died from cerebral hypoxia secondary to asphyxiant inhalation at the scene of the fire. One patient died of cerebral edema of an unknown etiology.

Fulminant hepatic failure was responsible for three deaths. All three patients were middle-aged males with significant ethyl alcohol abuse histories. All had significant hepatic disease prior to injury. Their mean age was 51.7 ± 1.8 years, and mean burn size 29 ± 4.8 %. The mean predicted mortality for this small group of patients was 5 %. It must be noted that the predictor does not take into consideration pre-existent disease such as hepatic failure.

One patient of the 93 died from a pulmonary embolus. This was a 63-year-old morbidly obese female with a 30 % TBSA burn, inhalation injury, and pneumonia. This patient sustained a massive pulmonary embolus on postburn day 30 despite heparin prophylaxis at an infusion level sufficient to maintain a partial thromboplastin time between 40 and 50 s.

Four patients died from aspiration. Three of the four patients had pre-existing psychiatric disease, and all three died from immediate cardiopulmonary arrest. One patient developed prolonged respiratory failure following aspiration of gastric contents and eventually died of pulmonary failure. At autopsy numerous staphylococcal pulmonary abscesses were identified. The mean age of this group of patients was 48 years and mean burn size was 41 %.

Two patients died from massive adrenal infarction documented at autopsy, but not diagnosed premortem. Neither patient had systemic sepsis at the time of death. The first was a 25-year-old male with an 89 % burn who died on postburn day 12. The second was a 41-year-old male with a 64.5 % burn who died on postburn day 20. Both patients had sustained inhalation injury and had documented pneumonia which was treated with appropriate antibiotics. At autopsy, no discernable cause for adrenal infarction could be found.

Despite our ability to resuscitate the majority of patients from their initial injury, 13 % of the deaths in the past 5 years were secondary to our inability to achieve cardiopulmonary stability in the first 2 postburn days. Despite the decline in infection as a cause of death in burn patients, it is still the leading cause of demise in thermally injured patients. As is apparent from this review, the focus of infection has shifted from the burn wound to the lung. Of the 47 infection-related deaths which occurred in 1979, the focus of infection was the lung in 28 (59.6 %) and the wound in 12 (25.5 %). Between 1987 and 1991, the lung was the primary focus in 79.8 % of 39 patients who died of infection. The wound accounted for only 5.1 % of infection-

Table 4. Mortality (1979) segregated by age and burn size

TBSA	Age			
	< 20	21-40	41-60	> 60
< 20	0%	0%	0%	40%
21-40	6.6%	0%	36%	60%
41-60	21.4%	18.7%	50%	77%
61-80	75%	77%	100%	100%
> 80	100%	100%	100%	100%

Table 5. Mortality (1987–1991) segregated by age and burn size

TBSA	Age			
	< 20	21–40	41–60	> 60
< 20	0.4%	0%	2.5%	11.5%
21–40	0%	0.9%	15.4%	34.6%
41–60	24.1%	7.6%	33.3%	80%
61–80	0%	12.5%	60%	100%
> 80	75%	72.2%	75%	75%

related deaths. Inhalation injury and subsequent pneumonia are still significant co-morbid factors. Survival rates have significantly improved over the past decade, especially in mid-size burns (40–80 % TBSA) in middle aged adults (20–60 years) (Tables 4, 5). The improvement in survival is related to many changes in patient care, including infection control, burn wound excision, nutritional care and, most recently, the use of high-frequency ventilation in patients with inhalation injury. Not surprisingly, pre-existing cardiac, neurologic, and hepatic disease may have significant co-morbid effects on outcome, especially in the elderly. The gradual lengthening of the mean post burn day of death over the past decade reflects the improved level of critical care which is applied to critically ill severely burned patients. Despite this improvement, failure to obtain prompt wound closure in patients with massive thermal injury places them at risk for development of late complications, principally infection, which adversely affect outcome.

References

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